

Please check the examination details below before entering your candidate information

Candidate surname					Other names				
Centre Number					Candidate Number				

Pearson Edexcel Level 3 GCE

Tuesday 18 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9CH0/02**

Chemistry
Advanced
PAPER 2: Advanced Organic and Physical Chemistry

You must have:
 Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
 – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
 – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ►

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Answer ALL questions.

Some questions must be answered with a cross ☐. If you change your mind about an answer, put a line through the box ☐ and then mark your new answer with a cross ☐.

- 1 This question is about organic compounds that contain a halogen atom or a nitrogen atom.

- (a) Equal amounts of four bromoalkanes were added to separate test tubes containing 2 cm^3 of a silver nitrate solution.
The mixtures were heated in a water bath.

Which bromoalkane would be the **first** to form a precipitate?

(1)

- ☐ **A** 1-bromobutane
☐ **B** 2-bromobutane
☐ **C** 1-bromo-2-methylpropane
☐ **D** 2-bromo-2-methylpropane

- (b) Which pair of reactants will form an *N*-substituted amide?

(1)

- ☐ **A** CH_3COCl and NH_3
☐ **B** $\text{CH}_3\text{CH}_2\text{OH}$ and NH_3
☐ **C** CH_3COCl and CH_3NH_2
☐ **D** $\text{CH}_3\text{CH}_2\text{OH}$ and CH_3NH_2

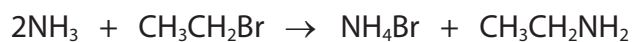
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(c) Ammonia reacts with bromoethane as shown.



- (i) Explain, by referring to the reaction mechanism, the roles of ammonia in the formation of each of the products of this reaction.

(3)

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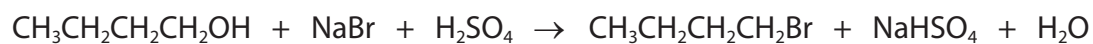
- (ii) What conditions are needed for this reaction?

(1)

	Method of heating	Solvent
☐ A	heat in a sealed tube	ethanol
☐ B	heat under reflux	ethanol
☐ C	heat in a sealed tube	water
☐ D	heat under reflux	water



- (d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.



Calculate the atom economy, by mass, for the formation of 1-bromobutane. Give your answer to **one** decimal place.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Br = 79.9]

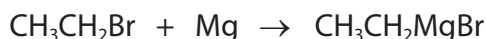
(2)

(Total for Question 1 = 8 marks)



2 This question is about Grignard reagents.

A Grignard reagent is formed by reacting bromoethane with magnesium under reflux.



(a) The most suitable solvent for this reaction is

(1)

- ☐ A cyclohexane
- ☐ B ether
- ☐ C ethyl ethanoate
- ☐ D hexane

(b) State the use of Grignard reagents in organic synthesis.

(1)

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(c) In their reactions, the Grignard reagent is best described as

(1)

- ☐ A a carbocation
- ☐ B an electrophile
- ☐ C a nucleophile
- ☐ D a radical

(d) Grignard reagents must be kept dry.

Predict the **organic** product that forms when $\text{CH}_3\text{CH}_2\text{MgBr}$ reacts with water.
Justify your answer by considering the polarity of both $\text{CH}_3\text{CH}_2\text{MgBr}$ and water.

(2)

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(e) Which compound will form a **tertiary** alcohol when it reacts with a Grignard reagent, followed by acid hydrolysis?

(1)

- ☐ **A** CO_2
- ☐ **B** HCHO
- ☐ **C** CH_3CHO
- ☐ **D** CH_3COCH_3

(Total for Question 2 = 6 marks)



3 This question is about hydrogen peroxide, H_2O_2 .

(a) Draw a dot-and-cross diagram of a molecule of hydrogen peroxide.

(1)

(b) Hydrogen peroxide decomposes to form water and oxygen.



Explain, using oxidation numbers, why the decomposition of hydrogen peroxide is classified as a disproportionation reaction.

(3)

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(c) The decomposition of hydrogen peroxide is catalysed by iodide ions, $\text{I}^-(\text{aq})$.

The kinetics of this reaction were investigated using different concentrations of hydrogen peroxide and iodide ions.
The results are shown in the table.

Experiment	$[\text{H}_2\text{O}_2(\text{aq})] / \text{mol dm}^{-3}$	$[\text{I}^-(\text{aq})] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.100	0.0500	8.90×10^{-7}
2	0.400	0.0500	3.56×10^{-6}
3	0.200	0.100	3.56×10^{-6}

(i) Deduce the order of reaction with respect to hydrogen peroxide and to iodide ions.

(2)

Order with respect to hydrogen peroxide

Order with respect to iodide ions

(ii) Write the rate equation for the reaction using your answer to (c)(i).

(1)

(iii) Calculate the rate constant, k , using data from Experiment 3.
Include units in your answer.

(2)



- (d) The breakdown of hydrogen peroxide with iodide ions as a catalyst is the basis of the demonstration 'Elephant's Toothpaste'.

The presence of a detergent results in a rapid eruption of foam as the oxygen gas is released.

- (i) Describe the test and the positive result that confirms the gas produced is oxygen.

(1)

- (ii) The foam produced often has a slight yellow / brown colour.

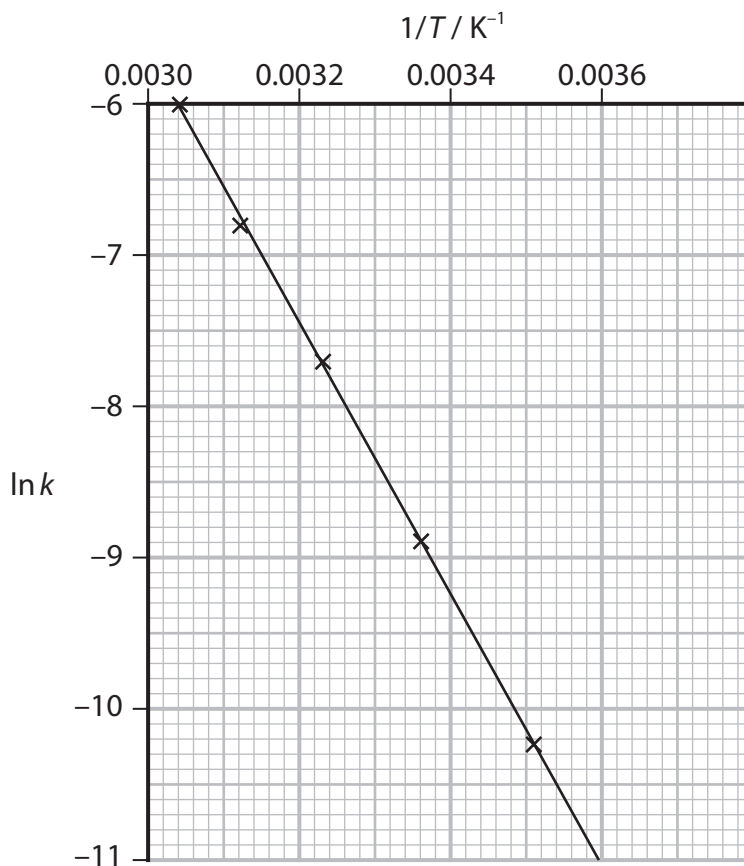
Explain what causes this colour, which is **not** caused by the detergent.

(2)



- (e) The effect of temperature on the rate of the decomposition of hydrogen peroxide without a catalyst was also investigated.

A graph of $\ln k$ against $1/T$ was plotted.



- (i) Determine the gradient of the graph.
Include units in your answer. You must show your working on the graph.

(3)



- (ii) Calculate the activation energy, E_a , of the reaction, in kJ mol^{-1} , using your answer to (e)(i) and the Arrhenius equation shown.

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

[Gas constant (R) = $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$]

(1)

- (f) Another way to write the Arrhenius equation is shown.

$$k = Ae^{-E_a/RT}$$

The constant A is often called the collision factor as it is linked to the orientation of the particles colliding in a reaction.

The decomposition of hydrogen peroxide is also catalysed by aluminium.

Calculate a value for A at 370 K , for the catalysed decomposition of hydrogen peroxide with an activation energy, E_a , of $5.02 \times 10^4 \text{ J mol}^{-1}$ and a numerical value for the rate constant of 1.60×10^{-3} .

Units are **not** required.

(2)

(Total for Question 3 = 18 marks)

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- *4** Discuss the role society, and chemists in particular, can play in order to contribute to a more sustainable use of polymers.

Your answer should consider

- the different ways of dealing with waste polymers
- how chemists can limit the problems caused by the disposal of polymers.

(6)



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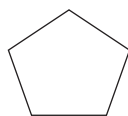
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(Total for Question 4 = 6 marks)



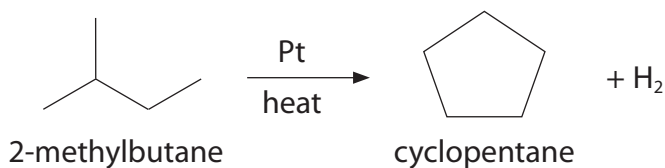
5 This question is about cyclic compounds.

- (a) The hydrocarbon cyclopentane is present in some fuels and is used in the manufacture of insulation for freezers.



cyclopentane

Cyclopentane can be synthesised by passing 2-methylbutane over a hot platinum catalyst.



Name the type of reaction that takes place in this synthesis.

(1)

- (b) The energy density of a fuel is defined as the energy released per dm^3 of the liquid fuel burned.

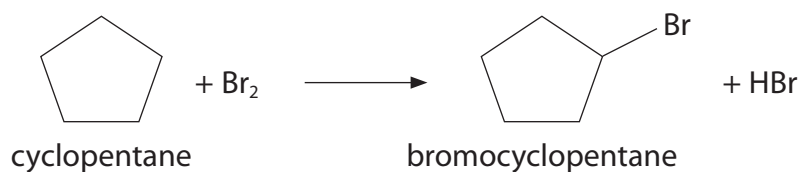
A sample of cyclopentane with a mass of 30.0 g releases 1.41 MJ of energy.

Calculate the energy density of cyclopentane.
Include units in your answer.

[Density of cyclopentane = 0.751 g cm^{-3}]

(2)

- (c) Under appropriate conditions, cyclopentane reacts with bromine to form bromocyclopentane.



- (i) State the condition needed to initiate the reaction.

(1)

- (ii) Complete the table showing the steps of the mechanism of this reaction. Curly arrows are not required.

(3)

Step	Equation(s)
Initiation	
Propagation	1. + Br• → + HBr 2.
Termination	→

- (iii) Draw the structure of the organic product of an alternative termination step.

(1)

- (d) Bromocyclopentane forms cyclopentene when heated under reflux with a concentrated solution of potassium hydroxide in ethanol.



- (i) Explain why the solvent ethanol is treated with anhydrous sodium sulfate before use in this reaction.

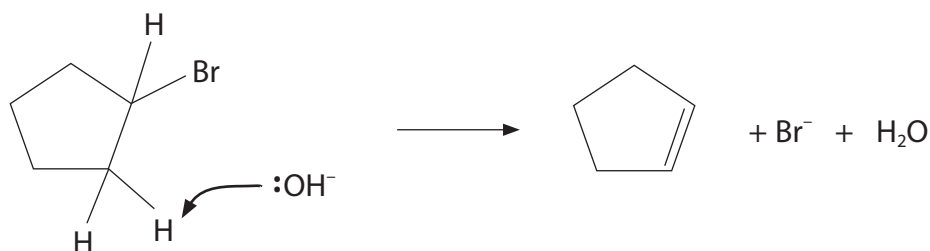
(2)

- (ii) Give the name of the reaction shown in the equation.

(1)

- (iii) Predict the mechanism for the reaction by adding two curly arrows.

(1)



(Total for Question 5 = 12 marks)

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6 This question is about nuclear magnetic resonance (NMR) spectroscopy.

(a) Which part of the electromagnetic spectrum is used in NMR?

(1)

- ☐ **A** infrared
- ☐ **B** radio waves
- ☐ **C** ultraviolet
- ☐ **D** X-ray

(b) Explain why tetramethylsilane, TMS, is used in NMR spectroscopy.

(2)

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(c) A secondary amine, **Q**, has the molecular formula $C_6H_{15}N$.
The low resolution ^1H NMR spectrum of **Q** has three peaks.

(i) State what is meant by the term 'secondary amine'.

(1)

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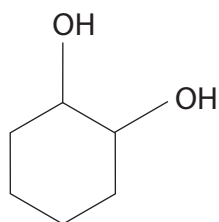
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(ii) Deduce the structure of **Q**.

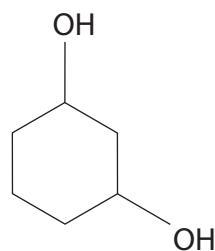
(1)



(d) Two cyclic alcohols have the structures shown.



cyclohexane-1,2-diol



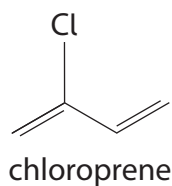
cyclohexane-1,3-diol

Show that the ^{13}C NMR spectra of these compounds can be used to distinguish between the two alcohols, labelling the diagrams to justify your answer.

(2)

(Total for Question 6 = 7 marks)

- 7 This question is about polymers, an example of which is neoprene, a synthetic rubber material.
It is formed by the polymerisation of chloroprene.



- (a) What is the IUPAC name of chloroprene?

(1)

- ☐ A 3-chlorobuta-1,3-diene
- ☐ B 2-chlorobuta-2,4-diene
- ☐ C 3-chlorobuta-2,4-diene
- ☐ D 2-chlorobuta-1,3-diene

- (b) Calculate the volume, **in cm³**, occupied by 10.0 g of chloroprene in the gaseous phase, at 80.0 °C and 205 kPa.
Give your answer to an appropriate number of significant figures.

[Gas constant (R) = 8.31 J mol⁻¹ K⁻¹]

(5)

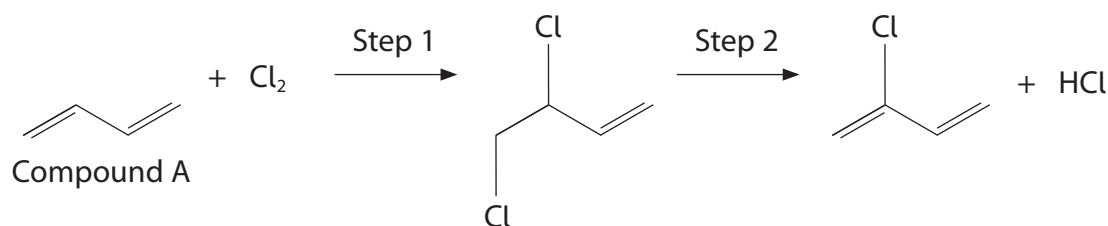
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- (c) Chloroprene is formed by first adding chlorine, Cl_2 , to Compound A and then removing hydrogen chloride from the product of this reaction.



- (i) Explain how chlorine, Cl_2 , can act as an electrophile in Step 1 even though a chlorine molecule is symmetrical. You may find it helpful to include a diagram.

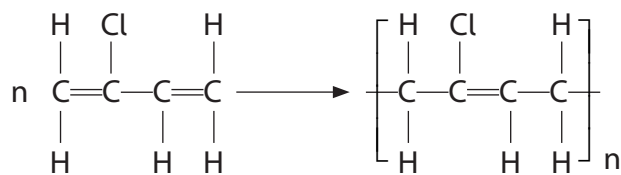
(2)

- (ii) Draw the mechanism for Step 1. Include curly arrows, and any relevant lone pairs and dipoles.

(3)



(iii) Chloroprene polymerises to form neoprene as shown.



Give the name of the type of reaction that occurs when chloroprene polymerises.

(1)

- (d) Flexible and water-resistant materials can be made by combining neoprene with polyester fabric.

A polyester may be made by the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

- (i) Explain why ethane-1,2-diol is soluble in water.
A detailed description of the forces involved is not required.

(2)

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- (ii) The molar mass of a polyester is 8400 g mol^{-1} .

Calculate the number of polymer molecules in 4.25 mg of this polyester.

[Avogadro constant (L) = $6.02 \times 10^{23} \text{ mol}^{-1}$]

(2)

- (iii) A student spilled a small amount of 0.40 mol dm^{-3} sodium hydroxide solution onto a polyester laboratory coat. A hole formed in the laboratory coat as the result of a chemical reaction.

What type of reaction occurred?

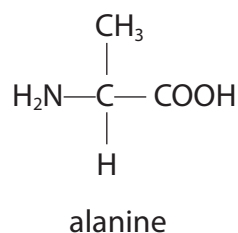
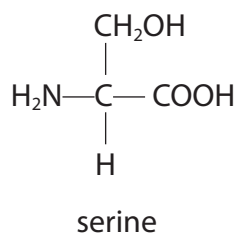
(1)

- ☐ A dehydration
- ☐ B hydrolysis
- ☐ C neutralisation
- ☐ D redox

(Total for Question 7 = 17 marks)

8 This question is about amino acids and related compounds.

The structures of two amino acids are shown.



(a) Both amino acids contain a chiral carbon atom.

(i) State what is meant by the term 'chiral carbon atom'.

(1)

(ii) Draw diagrams of the two stereoisomers of **alanine**, showing their three-dimensional shape.

(2)

(b) Draw the **skeletal** formulae of the two dipeptides that could form when serine and alanine react.

(2)

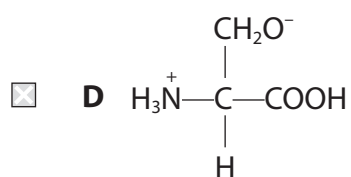
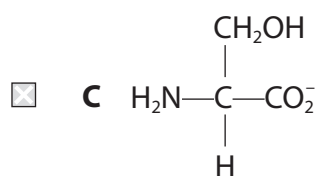
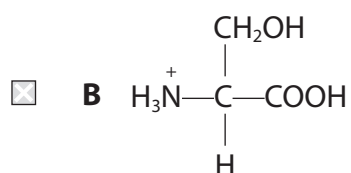
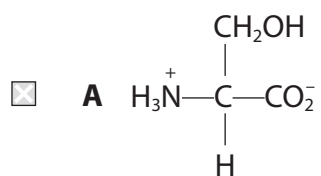
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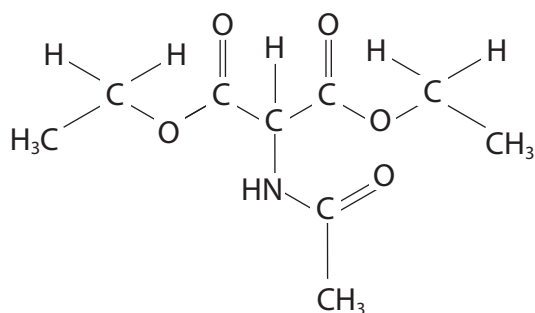
(c) Serine exists as a zwitterion.

What is the formula of this zwitterion?

(1)

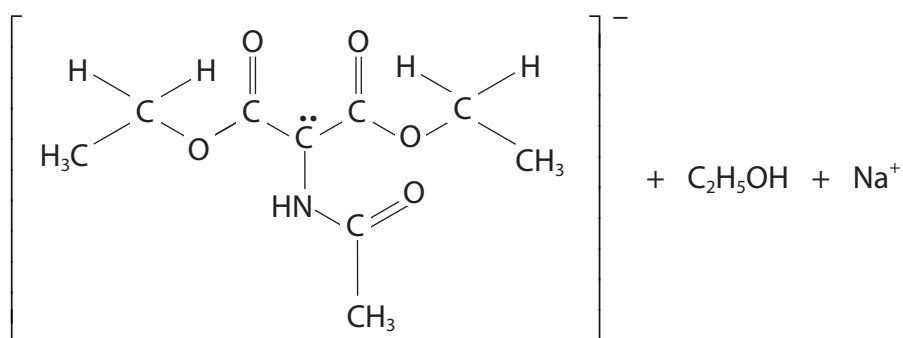
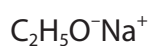


(d) Alanine can be synthesised as shown.

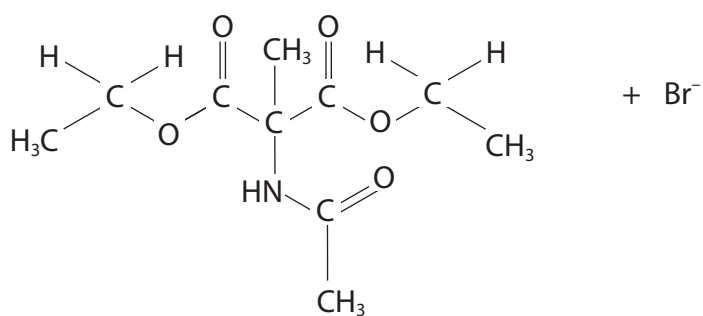


Compound **X**

Step 1

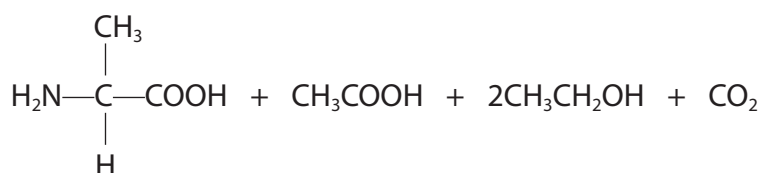


Step 2



Compound **Y**

Step 3



- (i) Sodium ethoxide, $\text{C}_2\text{H}_5\text{ONa}$, needed in Step 1, is formed by the reaction of sodium with ethanol.

Write the equation for this reaction.
State symbols are not required.

(1)

- (ii) Name the **two** functional groups present in Compound **Y**.

(2)

- (iii) Give the reagent needed and conditions required for Step 3.

(2)

- (iv) Calculate the mass of Compound **X** required to make 15.0 g of alanine, assuming the overall yield of the synthesis is 55 %.

(3)

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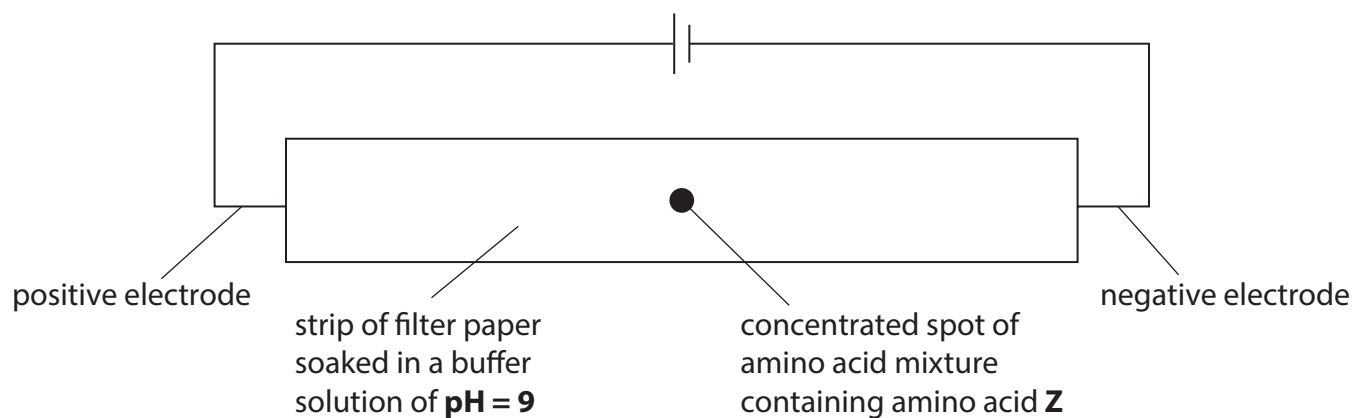
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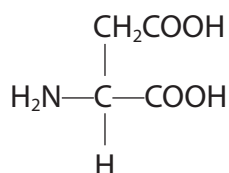


- (e) A mixture of amino acids can be separated using a technique called paper electrophoresis. A simplified diagram is shown.

The movement of the amino acid on the paper depends on any charge on the amino acid, and this is determined by the pH of the buffer solution.



Amino acid **Z** has the structure shown.



amino acid **Z**

Explain in which direction, if any, amino acid **Z** would move when a current flows in the circuit with a buffer solution of pH = 9.

(2)

(Total for Question 8 = 16 marks)

TOTAL FOR PAPER = 90 MARKS



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P 7 6 8 9 6 A 0 3 2 3 2

* Lanthanide series

* Actinide series

140	Ce	cerium	58	141	Pr	praseodymium	59	144	Nd	neodymium	60	[147]	Pm	promethium	61	150	Sm	samarium	62	152	Eu	europium	63	157	Gd	gadolinium	64	159	Tb	terbium	65	163	Dy	dysprosium	66	165	Ho	holmium	67	167	Er	erbium	68	169	Tm	thulium	69	173	Yb	ytterbium	70	175	Lu	lutetium	71
232	Th	thorium	90	238	U	uranium	92	[231]	Pa	protactinium	91	[237]	Np	neptunium	93	[242]	Pu	plutonium	94	[243]	Am	americium	95	[247]	Cm	curium	96	[245]	Bk	berkelium	97	[251]	Cf	californium	98	[254]	Es	einsteinium	99	[253]	Fm	fermium	100	[256]	Md	mercurium	101	[254]	No	nobelium	102	[257]	Lr	lawrencium	103

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